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PROSPECTS FOR ELECTROWEAK PARAMETER MEASUREMENTS AT CDF

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ABSTRACT

The 4 pb^{-1} of 1.8 TeV $\bar{p}p$ collisions accumulated by the Collider Detector at Fermilab (CDF) have allowed various measurements of electroweak parameters. Three years from now results should be forthcoming on a sample of about 80 pb^{-1} which, in the likely context of that time, will still be quite significant.

1. Introduction

Various aspects of the production of W and Z particles in $\bar{p}p$ collisions have been studied by the Collider Detector at Fermilab (CDF). Production kinematics tends to be a fertile ground for studying QCD. Measurements of the properties of the W and Z particles on the other hand can be used to determine the basic parameters of electroweak theory. Although the LEP program will likely continue to dominate in the determination of electroweak parameters, some measurements which would be possible with additional data from the Tevatron Collider should still be important.

2. Scenario

CDF is a general purpose solenoidal detector system for the study of large transverse momentum physics at the Tevatron Collider. The current data sample continues to be the 4 pb^{-1} taken during 1988-89. Triggers on total transverse energy (E_T), cluster E_T, electrons, muons, dileptons, missing E_T and taus were recorded. New data should start to be taken early in 1992. Fermilab has scheduled a two year collider run to be interrupted briefly by the installation of the linac upgrade. Integrated luminosity goals have been stated as 25 pb^-1 for the first part of the run and 100 pb^{-1} for the total. If CDF can record data with a reasonable efficiency, say 80%, then 3 years from now we will be describing analyses of an 80 pb^{-1} sample. The detector will have been upgraded to have triggerable muon coverage over the full field analysis region of the solenoid, a vertex detector to enable b tagging, and various upgrades to allow trigger threshold levels used in the past to continue into the higher luminosity running and to achieve

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a more reasonable data collection efficiency. The presence of a second detector at D0 should add to the excitement.

During this period one may assume that the LEP detectors will record about 10 million Zs each and that the LEP-2 program will get started with perhaps a couple hundred W pair events recorded. The HERA program will be in full swing.

For the sake of definiteness let me assume the following scenario: the Higgs remains elusive. The lower limit on the Higgs mass slowly grows. The top quark mass is constrained to ± 20 GeV by LEP data and indications of its presence are seen in CDF and D0 data. This is the context for evaluating future electroweak measurements.

3. Electroweak Parameters

The basic parameters of electroweak theory are the masses and couplings of its force carriers, γ, W, Z and H. The masses and mixings of matter are largely separate. In leading order the theory is described by three parameters, two couplings and a mixing, which can be taken from three well measured numbers: α - known to 0.045 ppm, G_μ^F - known to 17 ppm, and the Z mass which for resonance depolarization in LEP could be measured to 60 ppm (6 MeV/c^2). The Higgs is decoupled.

Given the precision of measurements, leading order is clearly inadequate. A triumph of electroweak theory is renormalizability, and many higher order calculations have been done.[1] These calculations illustrate a sensitivity of observables to the presence of high mass objects in loops - objects which would otherwise be decoupled. There are dependences on the top quark mass (quadratic), on the Higgs mass (logarithmic), and on the masses of many types of heavy particles, such as in technicolor models.[2] These might be found or limited.

In the current level of experimental precision, multiple measurements, ignoring hypothetical particles, give a constraint on the top quark mass. In the absence of statistical error for the global LEP measurement, the allowed Higgs mass range corresponds to ± 20 GeV in top mass. Once the top mass is better known, there will be a constraint on the Higgs mass. If that in turn becomes known, we will be reduced to dealing with hypothetical scenarios.

4. Measurements

4.1. Measurements Not Likely to be Competitive

Although it is historically significant, the CDF measurement of the Z mass and width[3] has lost its relevance. The measurement will need to be repeated with new data however in order to demonstrate understanding of both energy scale and resolution. Depending on the degree of success in understanding the effects of the material of the new silicon vertex detector on the E/p calibration for electrons, the future CDF electron energy scale may be defined from the Z mass.

The forward/backward asymmetry in leptonic Z decays is a measurement similar to forward backward asymmetries measured by LEP experiments.[5] This is not very competitive $\sin^2\overline{\Theta}_W = 0.228^{+0.017}_{-0.015}$, but the uncertainty is essentially statistical.

4.2. *Measurements Which are Really QCD/PDF*

Implicit in the cross section measurements[6] are measurements of the rapidity distribution of produced W's and Z's which if accurate enough could constrain parton distribution functions (PDFs). The charge asymmetry in centrally produced W decay turns out to be a sensitive measure of the PDF up/down ratio.

The transverse momentum of produced W's and Z's[7] has been an area where QCD calculational techniques have been developed and demonstrated. One hopes that correlations and characterizations of the jet structure accompanying W and Z production will be a demonstration that QCD can be accurate.

4.3. *Measurements Remaining Important for Electroweak Parameters*

Measuring the rate of $W \rightarrow \tau\nu$ provides an unique test of lepton universality as described elsewhere.[8] The total number of W's at LEP-2 will not be sufficient to match the precision which will be possible at CDF if appropriate triggers can be retained. We may eventually complement e^+e^- tau decay data.

The search for W′ and Z′ is also described elsewhere.[9] This will remain the province of the Tevatron Collider until LHC or SSC turns on, although the return for luminosity diminishes as the limits approach 1 TeV.

The ratio of leptonic decay cross sections for W and Z production can be used with other standard model measurements to calculate the ratio $\Gamma(W)/\Gamma(Z) = 0.88 \pm 0.07$ from electron and muon data;[10] the Z width from LEP implies a value for the W width in agreement with known decay channels. This measurement should continue to improve with statistics. However, much of the interest in the result comes from the constraint on possible decays of the W to $t\bar{b}$ with eg. charged Higgs top decay modes. In the assumed scenario, this has become irrelevant. The W production rate at LEP-2 will be a good check.

The direct measurement of the W mass will continue to be of interest. Current best values are 79.91 ± 0.39 (CDF)[4] and 80.35 ± 0.38 GeV/c^2 (UA2).[11] These may be compared to the W mass inferred from the electroweak measurements at LEP of 80.14 ± 0.19.[12] Perhaps there is a desert. The CDF W mass accuracy to be expected may not quite scale with the improvement in statistics which implies an 80 MeV/c^2 measurement. For example, the theory error, labelled "structure functions" and taken to be 60 and 100 MeV/c^2 in the two analyses, will want improvement. The other uncertainties tend to scale with statistics except that if the luminosity is high enough to realize this scenario, the resulting overlapping minimum bias events will degrade transverse mass resolution; the lepton transverse momentum distribution may become more sensitive despite the increased dependence on the W P_T distribution. A measurement of the W mass to about 100 MeV/c^2 should be possible; the resulting constraint on possible new heavy particles should be quite significant.

Measurement of diboson production will advance beyond the possible observation of a few W γ events. The rate and particularly the angular distribution are sensitive to an anomalous magnetic moment of the W,[13] perhaps due to compositeness. Leptonic

W pair and W Z events may be seen but the W pairs will be smothered, presumably, by top background. LEP-2 should eventually settle things.

5. Further Outlook

Upgrades to the Tevatron Collider will allow further increases in luminosity at comparable instantaneous rates by increasing the number of bunches. Perhaps 6 or 7 years from now, we will be reporting results from a sample of about 1 fb^{-1}. Of course by that time LEP may be considering retirement, having measured the W mass to 75 MeV/c^2 or so, etc. A new hadron collider or two will be a forseeable as opposed to a distant prospect.

The most important electroweak measurement from a fb^{-1} sample will likely be the top mass. The higher rates at SSC/LHC will eventually allow this measurement to be eclipsed.

With the fb^{-1} sample a measurement of the W mass to about 50 MeV/c^2 is conceivable. The current state of ambiguity in electroweak theory calculations of the W mass is about 20 MeV/c^2.[14] With about 500 W γ events, the gauge zero in the angular distribution[13] should become apparent but perhaps old news. The Higgs may remain missing, but some constraint should be given on its mass. Of course there is always hope for a less conservative scenario, that some significant discrepancy will be found, teaching us something new.

References

1. See eg. *Z Physics at LEP 1*, ed. G. Altarelli, R. Kleiss and C. Verzegnassi, CERN 89-08.
2. M. Peskin and T. Takeuchi, *Phys. Rev. Lett.* **65** (1990) 964.
3. F. Abe et al. (CDF), *Phys. Rev. Lett.* **63** (1989) 1447.
4. F. Abe et al. (CDF), *Phys. Rev. Lett.* **65** (1990) 968, *Phys. Rev.* **D43** (1991) 664.
5. F. Abe et al. (CDF), subm. *Phys. Rev. Lett.*
6. F. Abe et al. (CDF), *Phys. Rev.* **D44** (1991) 91.
7. F. Abe et al. (CDF), *Phys. Rev. Lett.* **66** (1991) 2951, F. Abe et al. (CDF), subm. *Phys. Rev. Lett.*
8. A. Roodman (CDF), these proceedings.
9. T. Fuess (CDF), these proceedings.
10. The result of F. Abe et al. (CDF), *Phys. Rev. Lett.* **64** (1990) 152 has been updated and combined with preliminary muon results.
11. T. Pal (UA2), these proceedings.
12. J. R. Carter, Photon Lepton/EPS Conference, Geneva (1991).
13. K. O. Mikaelian, M. A. Samuel, D. Sahdev, *Phys. Rev. Lett.* **43** (1979) 746.
14. W. F. L. Hollik, *Forts. der Phys.* **38** (1990) 3.